U.S. Graduate Education

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Trends in Graduate Enrollment

Enrollment in U.S. graduate science and engineering (S&E) programs grew for almost 20 years, reached a peak of 436,000 students in 1993, and then began to shrink. From 1975-93, the overall number of students in graduate programs increased steadily at an average annual rate of 2 percent. Subsequent declining enrollment from 1993-97 has averaged 1.6 percent annually. Fewer students enrolling in engineering, mathematics, and computer sciences account for most of the decline. Engineering, mathematics, and computer science enrollments grew at a rate of almost 4 percent annually from 1975-92, but declined 3 percent annually from 1992-95. Engineering enrollment has continued to decline, while enrollment in mathematics and computer sciences increased slightly in 1996 and 1997. Trends differ when examining subfields: within the natural sciences, the physical sciences have decreasing graduate enrollment, while the biological sciences have increasing enrollment (NSF 1999a).

Graduate student enrollment in S&E, although shrinking, is becoming more diverse. In 1977, women represented only one-quarter of S&E graduate enrollment; by 1997, they represented 40 percent of enrollment. The increasing enrollment of minorities in graduate S&E programs partially stems from changing demographics—the higher growth rate in the minority population relative to the white population. While women and minorities continued a decade-long trend of increased enrollment in graduate S&E programs, foreign students and U.S. citizen white males began a downward trend in their enrollment levels. (See appendix tables 1 and 2 and NSF 1999a.) The decline in foreign student enrollment in U.S. institutions is likely influenced by the increasing educational opportunities in other countries.

Master's Degrees

The overall trend in U.S. S&E programs at the master's degree level shows rapidly increasing numbers of earned degrees throughout the 1980s and an even stronger growth in the 1990s. This growth is mainly accounted for by rising numbers of earned degrees in the social sciences and engineering, with relatively stable numbers in the natural sciences, mathematics, and computer sciences. (See appendix table 3.)

By Sex

Over the 20-year period 1975-95, males accounted for the strong growth in master's degrees in engineering, mathematics, and the computer sciences. Females were primarily responsible for the strong growth in social sciences; they also obtained a larger share of degrees in the natural sciences. The proportion of master's degrees earned by females increased considerably in the last two decades—not only in the natural sciences, but in engineering as well. In 1975, females earned 21 percent of the natural science degrees at the master's level and almost 3 percent of the engineering degrees. By 1997, females accounted for 43 percent of the natural science degrees and 16 percent of engineering. (See appendix table 3.)

By Race/Ethnicity

In the 1990s, minority groups in the United States earned, in most cases, increasing numbers as well as increasing shares of master's degrees in S&E fields. The number of S&E degrees earned by Asian/Pacific Islanders consistently increased, especially in engineering, mathematics, and the computer sciences. The number of S&E master's degrees obtained by blacks grew modestly in most fields, with strong growth in the social sciences. Hispanics earned a moderately increasing number—and proportion—of degrees in the social sciences, as well as in engineering. White students showed modest growth in natural science and engineering degrees in the 1990s and strong growth in the social sciences. Notwithstanding these gains, the share of master's degrees earned by white students in all fields declined during the 1977-97 period. (See appendix table 4.)

By Citizenship

Analysis of master's degrees by citizenship shows a trend toward a larger proportion of degrees going to foreign students in engineering, mathematics, and the computer sciences. In 1977, foreign students earned 22 percent of the engineering degrees and 11 percent of the mathematics and computer science degrees. By 1995, foreign representation at the master's level was 34 percent in engineering and 35 percent in mathematics and computer sciences. The rate of growth of overall S&E

master's degrees obtained by foreign students slowed somewhat in the 1993-96 period, mainly due to a leveling off of their earned degrees in mathematics and the computer sciences. (See appendix table 4.) Engineering degrees awarded to foreign students declined in 1997, echoing the decline in foreign graduate enrollment in engineering from 1993-96. (See appendix table 2.)

Doctoral Degrees

A decade of relatively stable production of S&E doctoral degrees granted in the United States from 1975-85 was followed by a decade of increasing production of such degrees; in 1996, over 27,000 S&E doctorates were awarded. Large increases in the numbers of earned degrees were evident in engineering, mathematics, and the computer sciences. The number of degrees in these fields doubled from 1985-96. (See figure 1.) The natural science fields—particularly the biological sciences—also contributed to the rising number of degrees during this period, increasing by 25 percent (NSF, 1999d).

By Sex

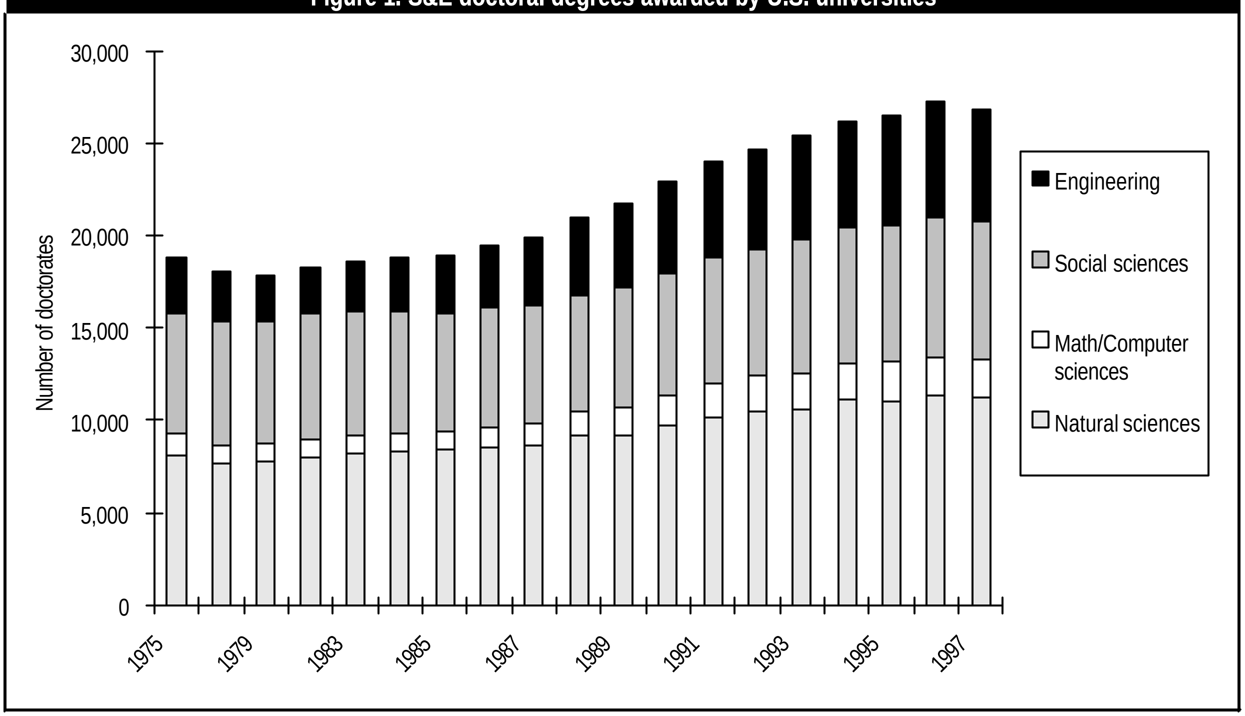
Male doctoral students accounted for much of the growth in engineering, mathematics, and the computer sciences; female doctoral recipients were largely responsible for the increasing number of natural science degrees. Within the past two decades, the share of S&E doctorates earned by women doubled, rising from almost 16 percent in 1975 to 33 percent in 1997. The proportion of increase has differed by field. By 1997, females earned half of the doctoral degrees in the social sciences and 40 percent in the biological sciences. Growth in the proportion of degrees awarded to women was greatest in engineering subfields. By 1997, women earned 12 percent of all engineering degrees, and 16 to 18 percent of doctoral degrees in chemical and material engineering. (See appendix table 5.)

By Race/Ethnicity

Underrepresented minorities within U.S. universities received over 7 percent of all S&E doctorates awarded to U.S. citizens and permanent residents in 1995; this was up slightly from 4 percent in 1977. As a group, these minorities received 6 percent of earned degrees in the natural sciences, 4 percent in mathematics and the computer sciences, 10 percent in the social sciences, and 6 percent in engineering.[1] For black Ph.D. recipients, the largest numerical increases in the past decade have been in the

[1]When considering the total number of earned S&E doctoral degrees (including those to foreign students), the percentages earned by underrepresented minorities are smaller. See NSB (1998), chapter 2.

Figure 1. S&E doctoral degrees awarded by U.S. universities



SOURCE: See appendix table 5.

biological and social sciences. The largest percentage increases have been in the biological sciences and engineering. (See appendix table 6.)

Graduate Education Reforms in the United States

Needs for Reform

The Committee on Science, Engineering, and Public Policy (COSEPUP) of the National Academy of Sciences recently reviewed U.S. graduate programs in S&E. The resulting report, *Reshaping the Graduate Education of Scientists and Engineers* (COSEPUP 1995), recommends broadening the education of doctoral students to better meet their actual career needs. The report noted that the current focus of doctoral programs on research training in a narrow discipline gradually evolved over previous decades when the demand for research was rising. U.S. R&D spending increased rapidly from the late 1970s to the latter part of the 1980s; consequently, doctoral R&D employment increased by almost 5 percent annually. Today, however—the report goes on to explain—an even smaller minority than previously will enter academic research. Only one-third of future doctoral recipients in S&E will enter the tenured academic system; two-thirds will be employed in nonacademic settings. The report concludes that doctoral course offerings should be expanded to reflect the diversity and complexity of these employment options. What these options will all require is the ability to apply an advanced understanding of science and engineering to societal needs. Consequently, S&E doctoral students will need:

- education in the broad fundamentals of their fields,
- familiarity with several subfields,
- the ability to communicate complex ideas to nonspecialists, and
- the ability to work well in teams.

Focus of Reforms

A variety of graduate reforms predated or stemmed from the recommendations of the COSEPUP report. These reforms focus on the education needs of students. Graduate programs are being expanded to include not only multidisciplinary coursework, but also to answer to students' needs for business and teaching skills. The Council of Graduate Schools has held a series of national discussions with graduate deans about the need to prepare students more effectively for their roles as future faculty. Subsequently, the 1997 meeting of the National Science Board on the Federal Role in Graduate and Postdoctoral Programs recommended Federal encouragement to universities to increase diversity and the appropriate broad training of the S&E labor force (NISE 1998).

Forces for Change

Underlying these policy studies are a variety of forces for graduate education reform. These include recent demographic, economic, technological and social changes, as well as the increasing complexity of viable solutions to real-world problems.

Among the demographic forces for change is a larger number of women and minorities earning bachelor's degrees in S&E fields for potential recruitment into graduate S&E programs (along with a declining population and enrollment of whites and declining enrollments of foreign students). Emerging reforms that build on this demographic trend are graduate enhancement programs for underrepresented minority students and recruitment and retention programs for women in science and engineering. For example, Rice University initiated a graduate program for increasing diversity in computational sciences, and the University of Arizona and Notre Dame University promote the Graduate Education for Minorities Consortium (GEM) of industries, colleges, and universities to increase minority recruitment and retention (NISE 1998).

Economic and technological forces are combining to influence changes in graduate education. Spiraling education costs—which are increasing faster than the cost of living—are contributing to the growth of proprietary (for-profit) universities with cost-effective programs. The capital expense of major research programs is necessitating shared research facilities. Collaborative agreements among consortia of universities are being made to ensure efficient use of resources and expertise of graduate faculty. For example, in a new doctoral program in technology management, a consortium of nine universities across eight states links the top laboratories and faculty of key technical specializations (such as digital communication systems and industrial composite materials). This arrangement allows the participants to ensure the broad education needed to manage such advanced technologies (NISE 1998).

Another force for change is technology. Information technologies and distance learning technologies are changing how instruction can be given. For example, Engineering Research Centers supported by the National Science Foundation (NSF) are developing multidisciplinary engineering curricula through interactive instructional modules. (These centers are briefly described below under "Background: Federal Support for S&E.") These modules can assist in teaching principles of diverse subjects using graphics, diagrams, and animation to convey key concepts, along with interactive exercises for practicing the principles' application. Through alternative instructional delivery systems, both graduate students in university classrooms and researchers within private companies can use this software.

The growing demand for public accountability is driving the U.S. educational system to improve instruction in mathematics and science. At the graduate education level, this demand for accountability is focused on the improvement of teaching, with an increased focus on the educational and career needs of students rather than the research needs of faculty. Several universities have initiated efforts to improve both graduate and undergraduate instruction in science and engineering, such as Preparing Future Faculty programs and training for teaching assistants (NISE 1998).

Another dynamic for change is an emerging demand for broadly educated Ph.D. recipients who are able to address the complexity of real-world problems and contribute to their solution. For example, at a recent forum for graduate education reform, the director of research for the U.S. Department of Energy explained that the department—which is one of the largest Federal supporters of basic research in the natural sciences—needs an S&T workforce that can flexibly cross disciplines to solve complex problems in several mission areas. Issues that need to be addressed by the department include the security of existing nuclear stockpiles, the development and use of new energy technologies, the health and environmental effects of energy use, and structural genomics (which combines the disciplines of biology and informatics) in the human genome program (NISE 1998).

The above innovations—as well as new multidisciplinary programs and other efforts to broaden the preparation of graduate students—were addressed at a recent National Institute for Science Education, University of Wisconsin at Madison, forum on graduate education. For more information, see NISE (1998).

S&E Graduate Support

During the course of their graduate careers, most S&E students are likely to be involved in some type of research activities.[2] S&E graduate students thus play a unique role in the U.S. academic research system, in that they are both an input to and an output of this system. U.S. research universities have traditionally coupled advanced education with research, thereby generating new knowledge and producing advanced S&E talent. This complex, symbiotic relationship is exemplified by the va-

Background: Federal Support for S&E

Scientists played a key role in World War II within Federal defense research sites; following the war, policymakers chose to support scientists within universities. The Vannebar Bush Report stated that an increasing number of highly qualified scientists and engineers would be crucial to the U.S. economy, and recommended public support of advanced students in science and mathematics within universities. That policy produced significant Federal support for university-based S&T research and the training of scientists and engineers. These funds increased further following Sputnik, the Cold War, and the creation of the National Institutes of Health (NIH) and the National Science Foundation. By the early 1960s, NIH funding of university research exceeded total funding of university-based research by the Department of Defense.* This compact between the Federal Government and universities has continued to the present, with Federal academic R&D reaching $21 billion (in 1992 constant dollars) in 1996 (NSB 1998).

*Cited by Robert Rosenzweig, former president of the Association of American Universities, see *Stanford Today* (1998).

[2]See chapter 5, "Integration of Research with Graduate Educa-

riety of support mechanisms and sources through which financial resources are provided to S&E graduate students.[3] Support mechanisms include fellowships, traineeships, research assistantships, and teaching assistantships.[4] Sources of support include Federal agency; non-federal support (from academic institutions, state and local governments, foreign governments, nonprofit institutions, and industrial firms); and self-support (from loans or personal or family financial contributions). Most graduate students are supported by more than one source and mechanism during their time in graduate school; they also often receive support from several different sources and mechanisms in any given academic year.

Trends in Support

The recent enrollment declines reported earlier for all S&E graduate students affected the number of full-time students in 1995. For the first time in almost two decades, enrollment of full-time S&E graduate students declined slightly in 1995. A 12-year trend of steady increases in enrollment of full-time graduate students whose primary source of support was the Federal Government also ended, as did an even longer upward trend in the number of graduate students whose primary source of support was from non-federal sources.[5] For more information on Federal support, see sidebar on Background: Federal Support for S&E. The number of self-supported graduate students also declined for the first time since 1988. (See appendix table 7.)

Since 1980, there have been significant shifts in the relative usage of different types of primary support mechanisms. (See figure 2.) These shifts have been due more to rapid growth in some support mechanisms than to an absolute decline in the number of students supported by any of these mechanisms. The proportion of graduate students with research assistantships as their primary support mechanism increased from 22 to 27 percent between 1980 and 1995. This increase was offset by drops in the proportions of students supported by traineeships (from 7 to 5 percent) or by teaching assistantships (from 23 to 20 percent). Most of these changes had occurred by the late 1980s, with proportional shares being relatively stable during the first half of the 1990s. The proportion supported by fellowships fluctuated between 8 and 9 percent between 1980 and 1995; that with self-support as the primary mechanism fluctuated between 28 and 32 percent. These overall shifts in support mechanisms were evidenced for both students supported primarily by Federal sources and for those supported by non-federal sources. (See appendix table 7.)[6]

Patterns of Support by Institution Type

The proportions of full-time S&E graduate students with primary support from various sources and mechanisms differ for private and public universities. (See figure 3.) A larger proportion of full-time graduate students rely primarily on self-support in private academic institutions as opposed to those in public institutions—39 versus 30 percent in 1995.

Non-federal sources are the primary source of support for a larger proportion of students in public institutions (50 percent) than in private ones (41 percent). At both private and public institutions, about 20 percent of students receive their primary support from the Federal Government.

A larger proportion of students attending public academic institutions rely on research assistantships and teaching assistantships as their primary support mechanism (30 and 23 percent, respectively) than those attending private institutions (21 and 13 percent, respectively). This is balanced by greater reliance on fellowships and traineeships in private institutions (14 and 8 percent, respectively) than in public ones (7 and 4 percent, respectively).

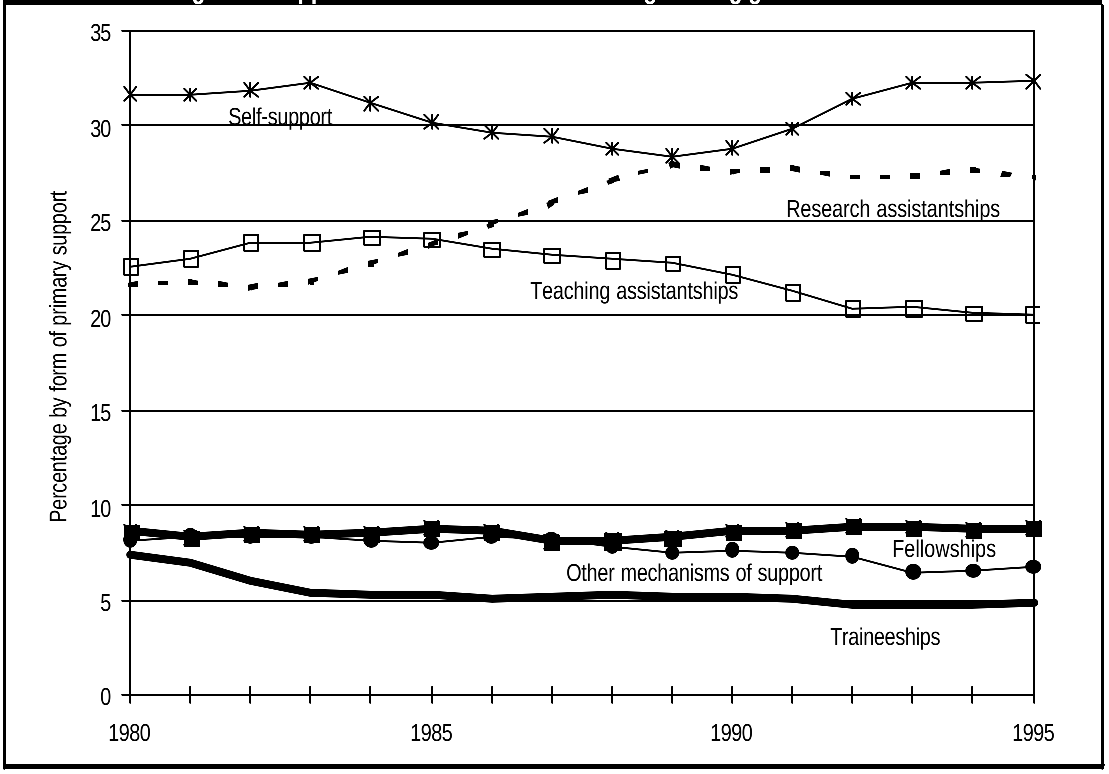
[3]All the data presented here on mechanisms and sources of support for S&E graduate students are from the NSF-NIH annual fall Survey of Graduate Students and Postdoctorates in Science and Engineering. In this survey, departments report the primary (largest) source and mechanism of support for each full-time degree-seeking S&E graduate student. No financial support data are collected for part-time students. Many of the full-time students may be seeking master's degrees rather than Ph.D.s, particularly in the engineering and computer science fields. Throughout this section on support, S&E include the health fields (medical sciences and other life sciences.)

[4]A *fellowship* is any competitive award (often from a national competition) made to a student that requires no work of the recipient. A *traineeship* is an award given to a student selected by the university. An *assistantship* is classified as research or teaching depending on the duties assigned to the student.

[5]Total Federal support of graduate students is likely to be underestimated since reporting includes only direct Federal support to a student and support to research assistants financed through the direct costs of Federal research grants. This omits students supported by departments through the indirect costs portion of research grants; such support would appear as institutional (non-federal) support, since the university has discretion over how to use these funds.

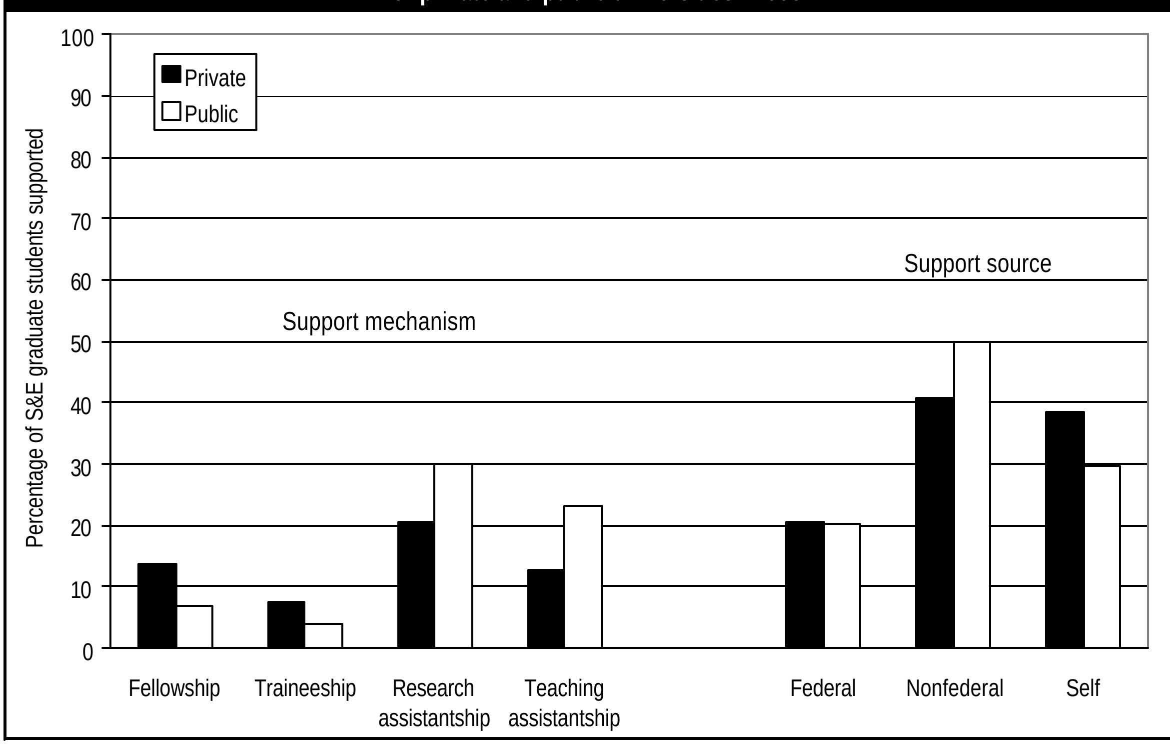
[6]For additional details on trends in support mechanisms by

Figure 2. Support for full-time science and engineering graduate students



SOURCE: See appendix table 7.

Figure 3. Percentage of S&E graduate students by mechanism and source of primary support, for private and public universities: 1995



NOTE: Mechanism percentages do not total 100 because other mechanisms are not included.

SOURCE: National Science Board, *Science & Engineering Indicators-1998,* NSB 98-1 (Arlington, VA: National Science Foundation), appendix table 5-35.

Primary Mechanism and Source of Support by S&E Field

Research Assistantships. Although research assistantships accounted for 27 percent of all primary support mechanisms in 1995, their role differed across S&E fields. They comprised more than 50 percent of the primary support mechanisms for graduate students in astronomy, atmospheric sciences, oceanography, agricultural sciences, chemical engineering, and materials engineering. They accounted for less than 20 percent in all the social sciences, mathematical sciences, and psychology. (See appendix table 8.)

Just as the significance of research assistantships differs across fields, so too does that of the Federal Government as the primary source of support for research assistantships. Overall, the Federal Government was the primary source of support for about half of graduate research assistants. However, it was the primary source of support for 75 percent of the research assistants in the physical sciences, just over 60 percent in both the environmental and computer sciences, but only 20 percent in the social sciences and 32 percent in psychology. (See appendix table 9.)

Teaching Assistantships. Teaching assistantships accounted for 20 percent of all primary support mechanisms in 1995. But they comprised more than 30 percent of the primary support mechanisms for graduate students in chemistry, physics, mathematics, and earth sciences; and less than 12 percent in the atmospheric sciences, oceanography, agricultural sciences, medical sciences, aeronautical engineering, and materials engineering. (See appendix table 8.) The Federal Government has an almost negligible role in supporting teaching assistantships.

Fellowships and Traineeships. Although fellowships accounted for only 9 percent of all primary support mechanisms in 1995, they are a much more important mechanism of primary support for students in the history of science, anthropology, and astronomy where they comprised 37, 20, and 17 percent of the primary support mechanisms, respectively. Students with traineeships as their primary support mechanism accounted for just under 5 percent of all full-time S&E graduate students in 1995. For students in the biological sciences, medical sciences, and other life sciences, however, traineeships accounted for between 11 and 14 percent of primary support. (See appendix table 8.)

The Federal Government was the primary source of support for about one-quarter of all graduate students with a fellowship as their primary mechanism of support and for about two-thirds of those with a traineeship as their primary mechanism of support. The Federal Government was a more important primary source for fellowships to graduate students in the atmospheric sciences, aeronautical engineering, and astronomy, providing 63, 56, and 50 percent, respectively, of the primary fellowship support. In contrast, it provided only 14 percent of primary fellowship support in the social sciences. The Federal Government provided almost 80 percent of primary support for traineeships in the life sciences, compared to 24 percent in computer sciences and 21 percent in the social sciences. (See appendix table 9.)

Self-Support. About one-third of full-time S&E graduate students were supported primarily by loans or from personal or family financial contributions. The importance of this type of support also differed across S&E fields. About 40 percent of students in the computer sciences, medical sciences, anthropology, and industrial engineering—and more than 50 percent of those in psychology and political science—relied on self-support as their primary support mechanism. Conversely, less than 10 percent of the students in astronomy, chemistry, physics, and the atmospheric sciences relied on self-support as their primary support. (See appendix table 8.)

Impacts of Graduate Support Mechanisms

There has long been great interest in whether the amount and type of financial support given to graduate students has an effect on degree completion rates, time to degree, and productivity and success in the labor market. How effective have the large investments in graduate education made by government, academia, and the private sector been? How do the various modes of support—teaching assistantships, research assistantships, fellowships, and subsidized loans—compare in terms of recipients' educational and career outcomes?

Hypotheses of Relative Merits. The merits of various support mechanisms have been discussed and a number of hypotheses developed about the advantages and disadvantages of different mechanisms. In fact, some of the characteristics of a specific mechanism cited as disadvantages by some individuals are cited as advantages by others. For instance, the portability of fellowships and the independence they give to graduate students are seen by some as a distinct advantage because they provide these students with great freedom to pursue a wide variety of interests. Others argue that students with fellowships are more likely than those supported by traineeships or research assistantships to become isolated from their peers and from the faculty in their departments; they thus may either be less likely to complete their Ph.D. or to take longer to do so. Some argue that although having a fellowship at the beginning of one's graduate career may be detrimental, having one when working on a dissertation is highly advantageous.

Similarly, some hold that since research assistantships are directed to the needs of funded research projects, doctoral students can become so involved on a specific project that they have little time for independent exploration or other educational activities, thus limiting the areas in which they acquire experience. A counter argument is that the research skills and experience students acquire by focusing on a specific project are indispensable to the high-quality, state-of-the-art research being conducted at U.S. universities and industrial laboratories; students with research assistantships thus may complete doctoral dissertations more frequently and faster than those with other forms of support. Some argue that strong reliance on research assistantships can bias research and graduate training toward those areas that have long track records rather than to new and innovate areas, and that they also may prevent beginning faculty from attracting graduate students. Others argue that it is the widespread availability of research grants that provides young faculty the opportunity to work closely with graduate students.

Lack of Quantifiable Data. Unfortunately, it is extremely difficult to examine many of these hypotheses analytically either because of the absence of data or the inability to capture the hypothesized outcomes quantitatively.[7] In addition, most graduate students depend on multiple sources and mechanisms of support while in graduate school, and frequently on different sources and mechanisms in different phases of graduate work. This makes it quite difficult, if not impossible, to identify a one-to-one relationship between a student and a support source or mechanism.

Furthermore, there is a selection problem that is not easily overcome. Most external organizations and graduate institutions award financial support based on merit. In addition, the type of support that a student receives is affected by a graduate department's view (and perhaps sometimes by the student's own view) of the student's relative ability to teach or to support research. If students receiving support have more ability or motivation than other students, the former are likely to be more successful than the latter irrespective of the effects of support mechanisms. To the extent that graduate support allocation decisions are successful in sorting students by merit and aptitude, it becomes more difficult to statistically isolate the effect of receiving graduate support from the effects of other student differences.

General Conclusions. Despite these difficulties, various studies have looked at some aspects of graduate support and student outcomes. A recent review of this literature summarized the results as follows (Bentley and Berger 1998):

- The bulk of the evidence suggests that students receiving support enjoy higher completion rates and shorter time to degree than students without support.

- The evidence of the differential effects of alternative support mechanisms on completion rates is inconsistent. However, students holding fellowships appear to finish doctoral programs more quickly than teaching and research assistants.

- Several scholars present evidence that research assistants are more productive scholars than other students, both in graduate school and later in their careers.

- Only one study included in this review attempts to determine whether the dollar amount of support matters. That study did not find evidence that increasing the amount of support improves outcomes.

[7]National Science Board (NSB). 1996 Report from the Task Force on Graduate and Postdoctoral Education NSB/GE 96-2. Arlington, VA: National Science Foundation. This task force, established in 1995 to examine the merits, mix, and impact of several modes of funding support used by NSF in graduate and postdoctoral education, concluded that sufficient links between national data and NSF support data did not exist, and so no recommendations could be made on

Employment of Degreed Scientists and Engineers

Appendix table 10 shows the distribution of those in S&E occupations in the United States. Of the 11.5 million people with some kind of S&E degree, only 3.2 million are in jobs strictly labeled as science and engineering.[8] Of these, nearly two-thirds are employed by private, for-profit employers. By this strict occupational measure of S&E workers, Ph.D. recipients make up 13 percent of the U.S. S&E workforce. If the definition were extended to include all workers with S&E degrees, the proportion of doctorate-holders would fall to 4 percent.

International Mobility of Doctoral Students and Recipients: Foreign Doctoral Students in the United States

In the past decade, foreign students have accounted for the large growth in S&E doctoral degrees in U.S. universities. The number of foreign S&E doctoral recipients graduated from U.S. universities doubled from over 5,000 in 1986 to 10,000 in 1996. This doubling translates to an 8-percent average annual increase. In contrast, the rate of increase in doctoral degrees to U.S. citizens averaged less than 2 percent annually (NSB 1998).

Within natural science and engineering fields, the proportion of doctoral degrees earned in U.S. universities by foreign citizens climbed from 25 percent in 1985 to 33 percent in 1994; it has since begun to level off. In 1997, the share of natural science and engineering degrees earned by foreign students decreased slightly to 31 percent. This drop was mainly due to a decline in doctoral degrees earned by South Korean and Taiwanese students. Both of these economies (which are major contributors of foreign graduate students to the United States) have increased their internal capacity for graduate education in S&E, evidenced by the increasing number of in-country doctoral degrees in these fields (NSB 1998).

Even as Asian students entered U.S. graduate programs in record numbers, Asian universities were expanding their own doctoral degree programs in S&E fields. These two phenomena are related. The desire to increase in-country capacity to educate students through the doctoral level necessitated sending students abroad so as to prepare more S&E faculty for expanded graduate programs within Asian universities. For the period 1988-94, the Asian effort to receive doctoral training in U.S. universities was particularly intense, as evidenced by an increase from 2,872 earned degrees in 1989 to 6,229 in 1994. The annual rate of growth in S&E doctoral degrees earned by Asian students during this period was over 17 percent. However, this rate of growth has slowed considerably in the last few years, and in 1997, the number of degrees earned by Asian students within U.S. universities declined.

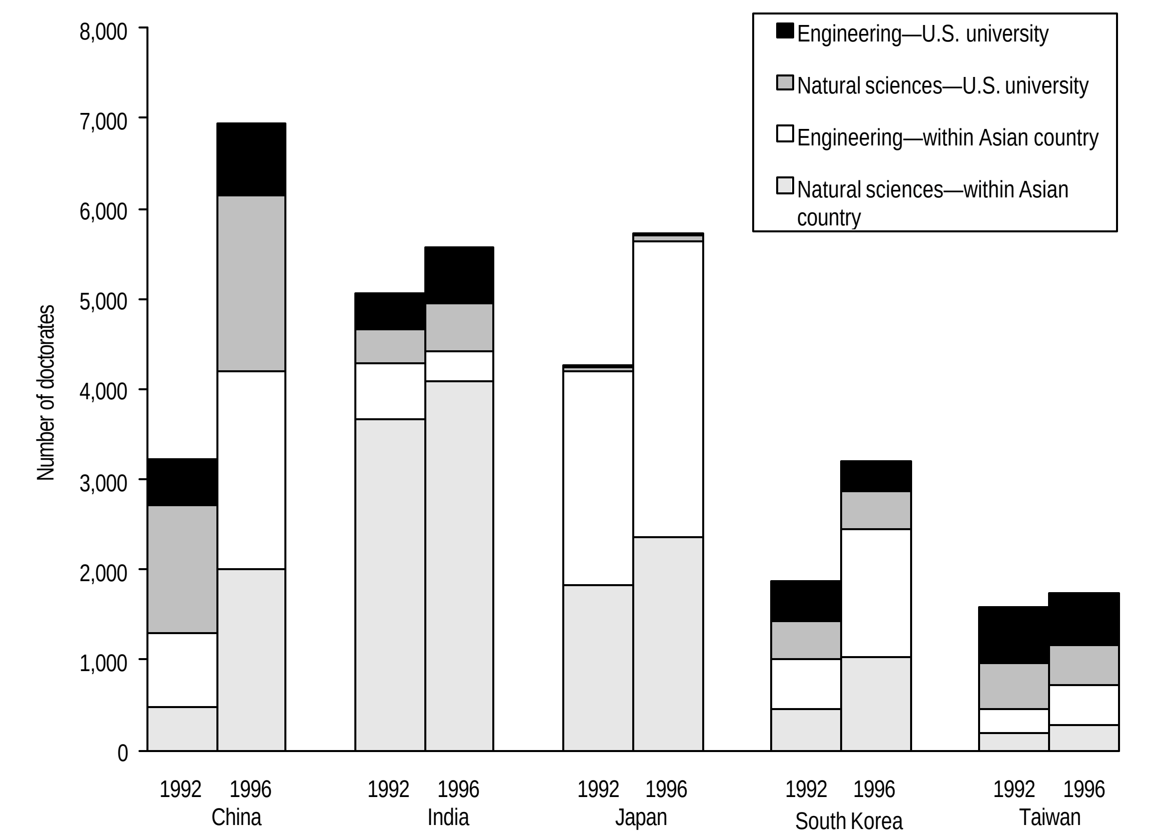
Although Ph.D. production in S&E fields is growing at a faster rate in Asian countries than in the United States, the Asian base is lower. In 1997, 18,513 S&E doctoral degrees were earned in five Asian countries. In that same year, U.S. universities produced almost 27,000 S&E doctorates; however, over 5,500 of these degrees were earned by foreign students from Asia. In 1997, the number of doctoral S&E degrees earned at universities within four Asian economies exceeded the number of such degrees earned by Asian foreign students at U.S. universities. Only for Taiwan do U.S.-earned doctoral degrees outnumber those earned within Taiwanese universities. (See figure 4 and text table 1.)

Patterns of International Mobility and Diffusion of S&T Knowledge

Technology transfer is often said to occur best through people. Thus, the mobility of foreign students throughout Europe, Asia, and the Americas is a significant source of diffusion of S&E knowledge in the world. NSF statistical data are limited to certain patterns of mobility to the United States. The Survey of Earned Doctorates captures the number of S&E doctoral degrees earned by foreign students, students' planned location after completing their degrees, and any firm offers they've received of U.S. postdoctoral study or employment. The Scientists and Engineers Statistical Data System (SESTAT) captures the extent of the contribution of foreign-born scientists and engineers to the U.S. labor force. Little is known,

[8] Other SESTAT survey responses provide strong evidence that many individuals with S&E degrees in non-S&E occupations do use their knowledge from their field of degree and may also be engaged in

Figure 4. Doctoral degrees in natural sciences and engineering awarded within Asian countries and to Asian foreign students within U.S. universities: 1992 and 1996



SOURCE: See text table 1.

Text table 1. Doctoral NS&E degrees awarded within Asian countries and to Asian foreign students within U.S. universities

Field and Location of Degree	Student nationality									
	China		India		Japan		South Korea		Taiwan	
	1992	1996	1992	1994	1992	1996	1992	1996	1992	1996
Total NS&E degrees	3,229	6,955	5,064	5,570	4,270	5,734	1,866	3,197	1,596	1,744
Natural sciences—within Asian country	473	1,999	3,665	4,077	1,833	2,351	459	1,024	191	282
Engineering—within Asian country	823	2,195	629	348	2,362	3,297	552	1,420	264	435
Natural sciences—U.S. university	1,425	1,960	365	520	50	54	418	430	504	452
Engineering—U.S. university	508	801	405	625	25	32	437	323	637	575

KEY: NS&E = natural sciences and engineering

NOTES: Natural sciences include the physical, biological, agricultural, earth, atmospheric, and oceanographic sciences, as well as mathematics, computer and information sciences. Data are latest available year for within-country degrees in India (1994).

SOURCES: **China**— National Research Center for Science and Technology for Development, unpublished tabulations, 1996; **India**—Department of Science and Technology, *Research and Development Statistics 1994-95* (New Delhi: 1996); **Japan**—Monbusho, Monbusho Survey of Education (Tokyo: annual series); **South Korea**—Ministry of Education, *Statistical Yearbook of Education* (Seoul:1996); **Taiwan**—*Educational Statistics of the Republic of China* (Taipei: 1997); **United States**—National Science Board, *Science & Engineering Indicators-1998,* NSB 98-1 Arlington, VA: National Science Foundation.

however, of the return flow of foreign students and the contribution they make to build the S&T infrastructure in their home countries. Little is also known of those foreign graduate students who do not complete a doctoral degree. For example, Japanese industry sends its research personnel to top U.S. universities for 1 to 2 years of advanced study in particular fields (NSF 1997).

The diffusion of S&T knowledge may also occur through networking, without physical relocation of scientists and engineers for extended stays. Choi (1995) has shown extensive networking by Asian-born faculty and researchers working in the United States to advise, disseminate information, and assist in building their home country S&T infrastructure. This tendency is particularly true for foreign-born faculty in S&E departments. In 1993, foreign-born faculty in U.S. higher education accounted for 37 percent of engineering professors and over a quarter of mathematics and computer science teachers. More research is needed on the extent of this diffusion of S&E knowledge through exchange visits or electronic dissemination.

Cooperative research and information technologies are also diffusing S&T knowledge. International cooperative science programs often provide support for immigrant scientists and engineers to collaborate with home country scientists and to advise on building up a research area in a particular area of interest. For example, many of the grantees in the NSF U.S.-China Cooperative Science Program are Chinese American scientists and engineers who are most able to work effectively within the Chinese environment. Electronic dissemination through the Internet is allowing the dissemination of innovative teaching modules as well as specific information needed by home country S&T institutions.

Stay Rates of Foreign Doctoral Recipients in the United States

Until 1992, around half of the foreign students who earned Ph.D.s in S&E in U.S. universities planned to locate in the United States after completing their degree. A significantly smaller proportion (one-third) received firm offers to remain in the United States for academic or industrial employment. The proportion of foreign doctoral recipients who plan to locate in the United States and accept firm offers differs considerably by country and region. Students from Asia, who are the most numerous, also represent the largest percentage who plan to locate in the United States. In contrast, students from North and South America, who are the least numerous, have a smaller proportion planning to locate in the United States.

For the period 1992-96, the proportions of foreign doctoral recipients planning to remain in the United States increased: over 68 percent planned to locate in the United States, and nearly 44 percent had firm offers to do so. This recent increase in stay rates, which may be temporary, is mainly accounted for by the sharp increase in the percentage of Chinese students with firm plans to stay in the United States. In 1990, 42 percent of the approximately 1,000 Chinese doctoral recipients in U.S. universities had firm plans to stay. By 1996, 57 percent of the nearly 3,000 Chinese doctoral recipients from U.S. universities had firm plans to remain in the United States. The underlying cause for this shift is the large number of Chinese students granted permanent residence status in the United States in 1992, following China's response to student demonstrations. Selected countries in Europe (Eastern Europe) and the Americas (Canada), however, also increased their stay rates after completing advanced degrees from a U.S. university. Their numbers are small in comparison to Asia's: 200 from Eastern Europe and 100 from Canada.

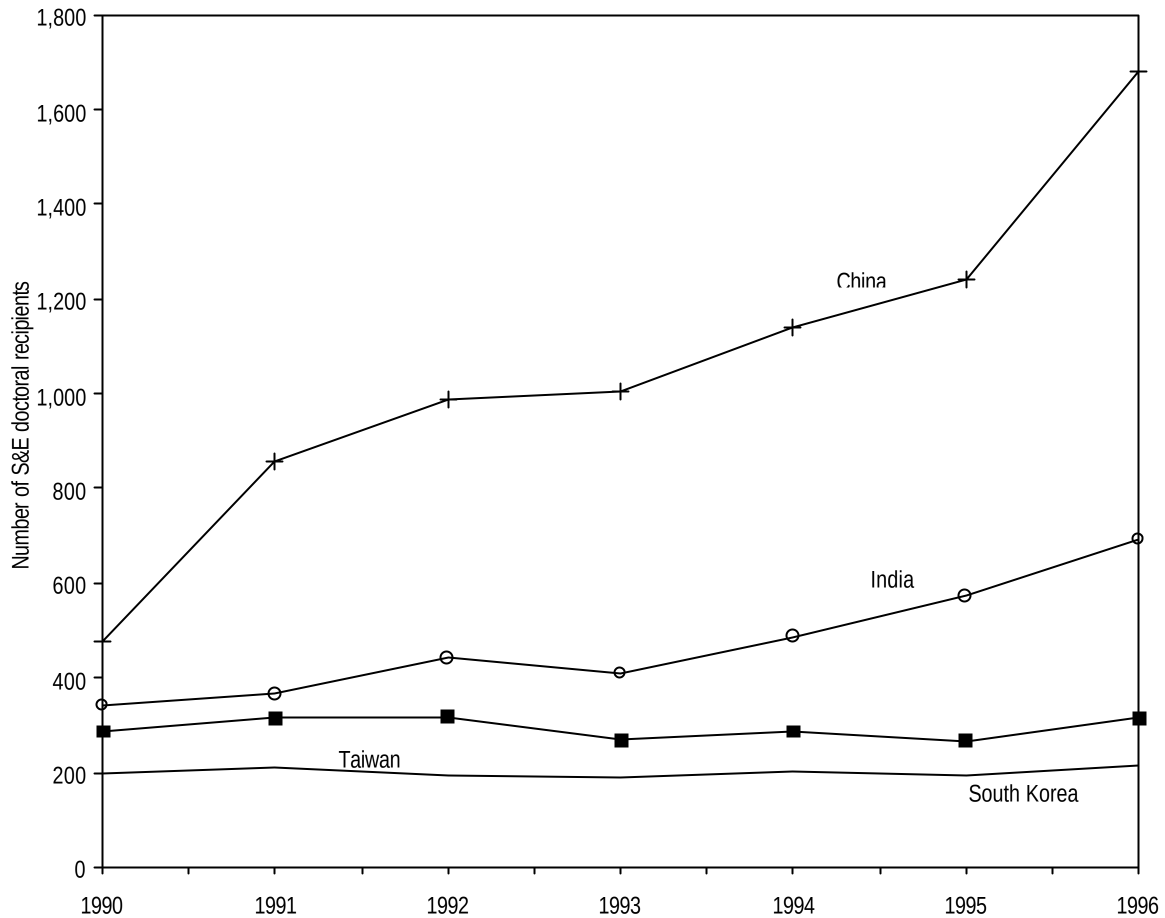
Among Asian countries, China and India apparently have a limited capacity to provide high-level employment to large numbers of returning S&E doctorate-holders. In 1996, 57 to 59 percent of the U.S. S&E doctoral recipients from these countries choose to accept further study or employment in the United States. In contrast, only a small percentage of 1996 doctoral recipients from South Korea and Taiwan (24 and 28 percent, respectively) accepted offers in the United States. The trend in the 1990s has been for relatively few doctoral recipients from these countries to remain in the United States; this is particularly true of South Korean engineering doctoral recipients (NSF 1998). (See figure 5.)

To a large extent, the definite plans of foreign doctoral recipients to remain in the United States revolve around postdoctoral study rather than employment. Among students born in those countries accounting for the largest numbers of foreign doctoral awards, the majority of definite plans to remain in the United States were for further study (58 percent on average between 1988 and 1996); followed by employment in R&D (27 percent); teaching (7 percent), or other professional employment (8 percent).

A recent study of foreign doctoral recipients working and earning wages in the United States (Finn 1997) shows that about 47 percent of the foreign students who earned doctorates in 1990 and 1991 were working in the United States in 1995. The percentages are higher in the physical sciences and engineering, and lower in the life and social sciences. These stay rates differ more by country of origin than by discipline, however. A very large percentage of the 1990-91 foreign doctoral recipients from India and China were still working in the United States in 1995. In contrast, only 10 percent of South Koreans who earned engineering doctorates from U.S. universities in 1990-91 were working in the United States in 1995.

Foreign doctoral recipients from 1970-72 were also examined in the same study. Finn estimated that 47 percent were working in the United States in 1995, and

Figure 5. U.S. S&E doctoral recipients from selected Asian countries with firm plans to remain in the United States



SOURCE: National Science Foundation, Division of Science Resources Studies, Survey of Earned Doctorates, special tabulations.

that the stay rate for that group had fluctuated around 50 percent during the 15 years leading up to 1995. There is no evidence of significant net return migration of these scientists and engineers after 10 or 20 years of work experience in the United States. This does not mean that there is not significant return migration: such migration is known to occur. However, the fairly constant stay rates indicate that any tendency of the 1970-72 cohorts to leave the United States after gaining work experience here has been largely offset by others from the same cohorts returning to the United States after going abroad.

Employment of Foreign-Born Scientists and Engineers

In total, there were 135,000 foreign-born S&E doctoral recipients working in the United States in 1993. (See text table 2 and appendix table 12.) They accounted for 25.6 percent of all U.S.-employed S&E doctorate-holders. Academia is the largest sector of employment for foreign-born S&E doctorate-holders. In industry, however, they actually make up a larger proportion of total S&E doctoral recipients: nearly one-third.

Asia was the place of birth for over half of the foreign-born S&E doctorate-holders working in the United States—76,000. Although this number is for the whole Asian continent, the two largest source countries combined—China and India—provided more S&E Ph.D. recipients to the U.S. labor force than all of Europe.

U.S. Doctoral Recipients Residing Outside the United States

In 1995, at least 19,600 U.S. native-born naturalized citizen and permanent resident Ph.D. scientists and engineers lived outside the United States (text table 3). These included:

Text table 2. Employed foreign-born science and engineering doctoral recipients in the United States

Place of birth	Total employed
All foreign-born	135,000
Percent of foreign-born of total S&E Ph.D.s employed	25.6
Africa	7,000
Asia	76,000
China	21.000
India	21.000
Japan	3.000
Korea	4.000
Taiwan	9.000
Other	18.000
Central/South America	10.000
Argentina	2.000
Brazil	1.000
Chile	1,000
Cuba	2,000
Mexico	1,000
Other	3,000
Europe	38.000
France	1.000
Germany	6.000
Greece	2.000
Italy	2.000
Netherlands	1.000
United Kingdom	10.000
Other	16.000
North America and other	8.000

NOTE: Numbers rounded to nearest 1,000.

SOURCE: National Science Foundation, Division of Science Resources Studies, 1993, Scientists and Engineers Data System (SESTAT) data file.

- 3 percent (13,900) of all native-born S&E doctorate-holders,
- 7 percent (1,400) of all foreign-born S&E doctorate-holders with U.S. citizenship at time of degree, and
- 14 percent (4,300) of all permanent resident S&E doctorate-holders at time of degree.

Not included are U.S. citizen Ph.D. scientists who held only a temporary student visa or work visa when they received their doctorate; it may be reasonable to assume that this group is as likely to work outside the United States as those who had already been naturalized by the time of degree.

The likelihood of foreign residence for U.S. natives is greatest for those with the most recent degrees—ranging from 2 percent of native-born doctorate-holders who received their Ph.D. between 1945 and 1954 to 3 percent of those who received their doctorate between 1985 and 1994. By field, the proportion of native-born Ph.D. recipients resident in foreign countries is greatest in the mathematical and computer sciences and in the social sciences (4 percent for each). It is lowest in the physical sciences.

Good estimates of the number of U.S. scientists and engineers who work abroad are not available, and the numbers presented here should be treated as lower bound estimates.[9]

[9]These estimates are based on a match of administrative data from the NSF 1995 Survey of Doctorate Recipients to individual data from the NSF Doctoral Record File created from the Survey of Earned Doctorates. The National Research Council (NRC) attempted to identify when a nonresponse was caused by the sampled individual residing outside the United States as of the April reference date. To the extent that individuals residing outside the United States are more prevalent in the sample portion never located by NRC than they are in the located sample, these numbers will underestimate the extent of emigration. Note that since a short-term trip abroad would not count as residence and since the Survey of Doctorate Recipients data are collected over several months, there is little danger of miscategorizing a short absence as working abroad. There is, however, a somewhat greater danger of listing a person as living abroad who left the United States for many years and has since returned.

Text table 3. Estimates of U.S. citizens and permanent resident Ph.D. graduates residing outside the U.S.: 1995

Field of Ph.D.	Native born		Foreign-born with citizenship at time of Ph.D.		Permanent resident at time of Ph.D.		Total citizen or permanent resident at time of Ph.D.	
	Number abroad	Percent of total abroad	Number abroad	Percent of total abroad	Number abroad	Percent of total abroad	Number abroad	Percent of total abroad
All S&E	13,900	3.3	1,400	7.4	4,300	13.6	19,600	4.1
Life sciences	3,400	2.7	200	5.0	900	12.0	4,500	3.3
Math and computer	1,000	4.2	100	4.2	200	10.2	1,200	4.6
Physical sciences	2,200	2.5	300	8.7	800	12.6	3,200	3.3
Social sciences	5,900	4.2	300	7.5	1,200	18.0	7,400	4.9
Engineering	1,500	3.0	500	9.1	1,300	13.1	3,300	5.0

NOTE: This should be considered a lower bound estimate since only those definitely identified as being outside the United States were counted.

SOURCE: National Science Foundation, Division of Science Resources Studies, Doctorate Record File and administrative records associated with collection of the 1995 Survey of Doctorate Recipients.

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APPENDIX

Appendix table 1. Graduate enrollment in science and engineering, by field and sex: 1975-97

Field	1975	1977	1979	1981	1983	1985	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
	Total enrollment																
Science and engineering	303,190	311,816	319,171	332,086	347,065	358,126	373,341	375,277	382,747	397,135	412,697	430,644	435,886	431,251	422,555	415,363	407,644
Natural sciences [a]	95,489	101,221	100,871	100,617	102,979	104,074	104,963	105,529	107,301	109,364	112,474	116,699	119,489	120,833	120,325	117,677	114,697
Mathematics/computer sciences	25,307	25,160	26,721	32,318	40,691	47,332	50,559	51,304	51,729	54,031	54,562	56,648	56,189	53,707	51,941	52,607	52,769
Social sciences [b]	114,123	116,750	119,851	119,596	112,276	110,729	113,866	115,615	119,674	126,115	132,085	139,262	143,350	143,688	143,090	141,856	139,170
Engineering	68,271	68,685	71,728	79,555	91,119	95,991	103,953	102,829	104,043	107,625	113,576	118,035	116,858	113,023	107,199	130,223	101,008
	Male enrollment																
Science and engineering	NA	233,862	229,860	232,209	240,525	247,464	256,149	254,005	256,849	263,394	271,845	280,397	279,289	272,120	262,341	253,629	245,615
Natural sciences [a]	NA	76,073	72,945	70,721	70,711	70,745	70,685	69,869	70,263	70,800	71,753	73,754	74,086	73,878	72,488	69,951	67,234
Mathematics/computer sciences	NA	19,482	20,376	23,628	28,877	34,417	36,948	37,334	37,756	39,633	39,994	41,644	41,129	39,087	37,554	37,596	37,008
Social sciences [b]	NA	73,322	70,687	66,051	59,625	57,391	57,526	57,097	58,387	60,008	62,237	64,197	64,908	64,181	63,114	61,111	59,080
Engineering	NA	64,985	65,852	71,809	81,312	84,911	90,990	89,705	90,443	92,953	97,861	100,802	99,166	94,974	89,185	84,971	82,293
	Female enrollment																
Science and engineering	NA	77,954	89,311	99,877	106,540	110,662	117,192	121,272	125,898	133,741	140,852	150,247	156,597	159,131	160,214	161,734	162,029
Natural sciences [a]	NA	25,148	27,926	29,896	32,268	33,329	34,278	35,660	37,038	38,564	40,721	42,945	45,403	46,955	47,837	47,726	47,463
Mathematics/computer sciences	NA	5,678	6,345	8,690	11,814	12,915	13,611	13,970	13,973	14,398	14,568	15,004	15,060	14,620	14,387	15,011	15,761
Social sciences [b]	NA	43,428	49,164	53,545	52,651	53,338	56,340	58,518	61,287	66,107	69,848	75,065	78,442	79,507	79,976	80,745	80,090
Engineering	NA	3,700	5,876	7,746	9,807	11,080	12,963	13,124	13,600	14,672	15,715	17,233	17,692	18,049	18,014	18,252	18,715

[a] Natural sciences here include physical, earth, atmospheric, oceanographic, biological, and agricultural sciences.

[b] Social sciences include psychology, sociology, and other social sciences.

KEY: NA= not available

NOTE: For detailed statistical tables on graduate enrollments, see Division of Science Resources Studies home page (http://www.nsf.gov/sbe/srs/stats.htm), Fall 1997 Supplementary Data Releases: Trends in Graduate Enrollment: 1975-1997.

SOURCE: National Science Foundation, Division of Science Resources Studies, *Graduate Students and Postdoctorates in Science and Engineering: Fall, 1997,* NSF 99-325 (Arlington, VA, 1999).

Appendix table 2. Graduate enrollment in science and engineering, by field, race/ethnicity, and citizenship: 1983-97

Field and race/ethnicity	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
	Total enrollment														
Science and engineering	347,014	349,875	358,201	368,212	373,425	375,287	382,769	397,135	412,697	430,644	435,886	431,251	422,555	415,363	407,644
Natural sciences [a]	102,968	103,547	103,990	105,541	104,974	105,529	107,301	109,364	112,474	116,699	119,489	120,833	120,325	117,677	114,697
Mathematics/computer sciences	40,713	42,985	47,341	49,316	50,575	51,304	51,729	54,031	54,562	56,648	56,189	53,707	51,941	52,607	52,769
Social sciences [b]	112,236	110,647	110,808	111,499	113,939	115,625	119,696	126,115	132,085	139,262	143,350	143,688	143,090	141,856	139,170
Engineering	91,097	92,696	95,982	101,856	103,937	102,829	104,043	107,625	113,576	118,035	116,858	113,023	107,199	103,223	101,008
	U.S. citizen enrollment														
Total S&E	276,784	277,682	281,388	284,231	284,631	281,672	284,686	294,318	304,063	321,182	330,169	329,095	324,017	317,209	308,835
Natural sciences [a]	84,700	84,712	83,663	82,854	80,562	79,431	79,242	79,521	81,148	84,893	88,164	89,890	90,648	89,276	87,376
Mathematics/computer sciences	30,306	31,532	34,499	35,448	35,669	35,895	35,352	36,561	36,306	38,041	38,135	36,580	35,338	34,991	34,413
Social sciences [b]	98,173	96,644	95,978	96,018	97,831	98,743	102,746	108,810	114,376	121,653	126,279	126,586	126,299	124,748	122,460
Engineering	63,605	64,794	67,160	69,911	70,569	67,603	67,346	69,426	72,233	76,595	77,591	76,039	71,732	68,194	64,586
White, S&E	224,705	224,705	224,705	224,705	224,705	229,037	229,694	238,472	243,602	253,435	256,859	255,719	245,889	238,077	227,936
Natural sciences [a]	74,337	74,046	71,971	71,713	69,100	68,737	68,110	68,736	69,472	71,328	72,552	74,134	73,296	71,777	69,021
Mathematics/computer sciences	23,823	24,040	25,511	26,053	26,806	27,479	26,560	27,897	26,921	27,744	27,332	26,205	24,398	23,644	22,432
Social sciences [b]	77,963	75,787	76,129	76,930	79,157	80,492	83,531	88,632	92,425	96,967	99,535	99,360	96,239	93,544	90,466
Engineering	48,582	48,582	48,582	48,582	48,582	52,329	51,493	53,207	54,784	57,396	57,440	56,020	51,956	49,112	46,017
Asian/Pacific Islander, S&E	9,353	10,172	12,000	12,775	14,572	15,188	15,693	17,155	18,136	21,752	24,059	26,474	25,901	25,947	26,078
Natural sciences [a]	2,378	2,526	2,712	2,761	3,043	3,478	3,604	3,928	4,267	5,035	6,162	6,606	6,778	6,899	6,835
Mathematics/computer sciences	1,666	1,816	2,491	2,770	3,235	3,438	3,430	3,710	3,724	4,362	4,586	5,264	5,174	5,494	5,754
Social sciences [b]	1,903	2,018	1,992	2,130	2,436	2,362	2,648	2,830	3,029	3,863	4,324	4,827	4,941	5,117	5,335
Engineering	3,406	3,812	4,805	5,114	5,858	5,910	6,011	6,687	7,116	8,492	8,987	9,777	9,008	8,437	8,154
Black, S&E	10,903	10,711	10,462	10,470	10,429	11,191	11,775	12,774	13,691	15,445	17,118	17,611	18,283	19,071	19,363
Natural sciences [a]	1,980	2,000	1,982	1,845	1,817	1,972	2,093	2,184	2,302	2,711	3,042	3,007	3,289	3,487	3,558
Mathematics/computer sciences	971	960	1,031	1,151	1,210	1,261	1,311	1,496	1,617	1,687	1,878	1,855	1,844	1,989	1,960
Social sciences [b]	6,574	6,306	6,062	6,022	5,986	6,458	6,755	7,308	7,747	8,673	9,639	9,965	10,294	10,700	10,971
Engineering	1,378	1,445	1,387	1,452	1,416	1,500	1,616	1,786	2,025	2,374	2,559	2,784	2,856	2,895	2,874

See explanatory information and SOURCE at end of table.

Appendix table 2. Graduate enrollment in science and engineering, by field, race/ethnicity, and citizenship: 1983-97 (Continued)

Field and race/ethnicity	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
	U.S. citizen enrollment														
Hispanic, S&E	8,811	8,681	8,613	8,660	8,823	9,098	9,436	10,159	11,045	12,246	13,381	13,281	14,117	14,638	14,988
Natural sciences [a]	1,919	1,892	2,092	2,118	2,071	2,228	2,386	2,375	2,552	2,726	3,075	2,933	3,209	3,338	3,574
Mathematics/computer sciences	615	585	750	723	817	844	847	916	980	1,082	1,111	1,002	1,064	1,126	1,152
Social sciences [b]	4,836	4,713	4,290	4,217	4,205	4,307	4,496	4,982	5,389	5,975	6,501	6,485	7,036	7,239	7,451
Engineering	1,441	1,491	1,481	1,602	1,730	1,719	1,707	1,886	2,124	2,463	2,694	2,861	2,808	2,935	2,811
American Indian/Alaskan Native, S&E	911	830	736	743	783	918	860	1,054	1,120	1,243	1,309	1,383	1,516	1,539	1,599
Natural sciences [a]	224	206	167	196	183	216	180	255	251	282	318	336	393	374	412
Mathematics/computer sciences	53	71	79	52	76	71	74	64	62	99	100	79	125	94	103
Social sciences [b]	454	361	368	365	401	488	484	583	622	685	680	726	767	837	846
Engineering	180	192	122	130	123	143	122	152	185	177	211	242	231	234	238
Unknown, S&E	22,101	24,179	25,825	23,961	21,160	16,240	17,228	14,704	16,469	17,061	17,443	14,627	18,311	17,937	18,871
Natural sciences [a]	3,862	4,042	4,819	4,221	4,348	2,800	2,869	2,043	2,304	2,811	3,015	2,874	3,683	3,401	3,976
Mathematics/computer sciences	3,178	4,060	4,637	4,699	3,525	2,802	3,130	2,478	3,002	3,067	3,128	2,175	2,733	2,644	3,012
Social sciences [b]	6,443	7,459	7,145	6,354	5,646	4,636	4,832	4,475	5,164	5,490	5,600	5,223	7,022	7,311	7,391
Engineering	8,618	8,618	9,224	8,687	7,641	6,002	6,397	5,708	5,999	5,693	5,700	4,355	4,873	4,581	4,492
	Foreign citizen enrollment														
Total S&E	70,230	72,193	76,813	83,981	88,794	93,615	98,083	102,817	108,634	109,462	105,717	102,156	98,538	98,154	98,809
Natural sciences [a]	18,268	18,835	20,327	22,687	24,412	26,098	28,059	29,843	31,326	31,806	31,325	30,943	29,677	28,401	27,321
Mathematics/computer sciences	10,407	11,453	12,842	13,868	14,906	15,409	16,377	17,470	18,256	18,607	18,054	17,127	16,603	17,616	18,356
Social sciences [b]	14,063	14,003	14,830	15,481	16,108	16,882	16,950	17,305	17,709	17,609	17,071	17,102	16,791	17,108	16,710
Engineering	27,492	27,902	28,822	31,945	33,368	35,226	36,697	38,199	41,343	41,440	39,267	36,984	35,467	35,029	36,422

[a] Natural sciences here include physical, earth, atmospheric, oceanographic, biological, and agricultural sciences.

[b] Social sciences include psychology, sociology, and other social sciences.

KEY: NA= not available

NOTE: For detailed statistical tables on graduate enrollments, see Division of Science Resources Studies home page (http://www.nsf.gov/sbe/srs/stats.htm), Fall 1997 Supplementary Data Releases: Trends in Graduate Enrollment, 1975-1997.

SOURCE: National Science Foundation, Division of Science Resources Studies, *Graduate Students and Postdoctorates in Science and Engineering: Fall, 1997,* NSF 99-325 (Arlington, VA, 1999).

Appendix table 6. Earned doctoral degrees by field, race/ethnicity, and citizenship: 1977–97

Field and race/ethnicity	1977	1979	1981	1983	1985	1987	1989	1991	1992	1993	1994	1995	1996	1997
							All doctoral degree recipients[a]							
All degrees	31,716	31,239	31,356	31,281	31,297	32,370	34,326	37,534	38,890	39,801	41,034	41,743	42,415	42,705
Science and engineering	18,008	17,872	18,257	18,635	18,935	19,894	21,731	24,023	24,675	25,443	26,205	26,535	27,230	26,847
Natural sciences [b]	7,676	7,817	7,995	8,194	8,436	8,655	9,185	10,164	10,437	10,530	11,082	11,033	11,392	11,256
Mathematics/computer sciences	964	979	960	987	998	1,190	1,471	1,839	1,927	2,026	2,021	2,187	2,043	2,001
Social sciences [c]	6,720	6,582	6,774	6,673	6,335	6,337	6,532	6,806	6,873	7,189	7,280	7,307	7,490	7,538
Engineering	2,648	2,494	2,528	2,781	3,166	3,712	4,543	5,214	5,438	5,698	5,822	6,008	6,305	6,052
							U.S. citizens and permanent residents							
All degrees	27,487	26,784	26,341	25,634	24,694	24,562	25,026	27,430	27,990	28,708	30,894	32,059	31,506	30,601
Science and engineering	14,881	14,711	14,654	14,518	14,065	14,055	14,591	15,914	15,942	16,573	18,187	18,996	18,628	18,005
Natural sciences [b]	6,427	6,604	6,640	6,706	6,634	6,450	6,628	7,063	7,039	7,092	8,106	8,362	8,067	7,809
Mathematics/computer sciences	769	778	713	664	631	671	824	969	996	1,099	1,200	1,387	1,159	1,122
Social sciences [c]	5,886	5,712	5,830	5,666	5,206	5,021	4,910	5,408	5,387	5,685	5,828	5,905	6,019	5,793
Engineering	1,799	1,617	1,471	1,482	1,594	1,913	2,229	2,474	2,520	2,697	3,053	3,342	3,383	3,281
White, all degrees	23,654	22,396	22,470	22,251	21,306	21,122	21,570	23,185	23,625	24,052	24,594	24,719	24,685	23,789
Science and engineering	12,875	12,314	12,573	12,671	12,169	12,052	12,501	13,323	13,326	13,737	13,889	13,902	13,999	13,623
Natural sciences [b]	5,598	5,620	5,771	5,981	5,903	5,663	5,800	6,111	6,019	5,950	6,123	5,978	5,952	5,866
Mathematics/computer sciences	671	658	610	569	527	548	688	774	803	886	880	988	834	827
Social sciences [c]	5,177	4,879	5,099	4,993	4,551	4,383	4,287	4,601	4,624	4,876	4,866	4,846	4,953	4,668
Engineering	1,429	1,157	1,093	1,128	1,188	1,458	1,726	1,837	1,880	2,025	2,020	2,090	2,260	2,262
Asian/Pacific Islander, all degrees	910	1,102	1,073	1,042	1,070	1,168	1,268	1,531	1,764	2,017	3,546	4,309	3,697	3,140
Science and engineering	745	884	827	780	809	925	986	1,180	1,345	1,610	2,989	3,671	3,091	2,527
Natural sciences [b]	342	377	344	359	346	369	403	474	560	686	1,481	1,858	1,550	1,255
Mathematics/computer sciences	42	55	56	54	50	67	76	123	138	156	259	345	251	205
Social sciences [c]	112	146	142	120	132	162	146	178	196	241	382	435	395	363
Engineering	249	306	285	247	281	327	361	405	451	527	867	1,033	895	704
Black, all degrees	1,191	1,112	1,110	1,005	1,043	910	962	1,166	1,116	1,280	1,279	1,477	1,457	1,476
Science and engineering	342	347	346	338	374	319	366	464	408	469	500	560	576	607
Natural sciences [b]	85	84	89	84	100	95	105	116	107	136	153	171	187	191
Mathematics/computer sciences	9	12	11	6	10	13	9	19	9	14	21	16	20	11
Social sciences [c]	233	231	227	219	230	186	219	274	243	269	272	302	295	308
Engineering	15	20	19	29	34	25	33	55	49	50	54	71	74	97

See explanatory information and SOURCE at end of table.

Appendix table 6. Earned doctoral degrees by field, race/ethnicity, and citizenship: 1977–97 (Continued)

Field and race/ethnicity	1977	1979	1981	1983	1985	1987	1989	1991	1992	1993	1994	1995	1996	1997
Hispanic, all degrees	489	547	529	608	634	708	694	867	909	973	1,030	1,061	1,105	1,181
Science and engineering	203	234	240	284	296	357	382	492	513	542	548	571	623	645
Natural sciences [b]	76	84	93	86	107	138	157	191	208	226	254	234	229	251
Mathematics/computer sciences	12	12	5	7	18	15	15	21	20	23	20	21	26	34
Social sciences [c]	91	114	126	162	149	170	163	220	214	227	208	239	270	265
Engineering	24	24	16	29	22	34	47	60	71	66	66	77	98	95
American Indian/Alaskan Native, all degrees	66	81	85	82	96	115	94	132	149	120	143	149	187	151
Science and engineering	31	29	28	30	41	53	53	56	69	43	64	69	96	71
Natural sciences [b]	14	6	8	13	21	20	25	27	26	17	24	26	34	24
Mathematics/computer sciences	1	1	1	1	0	3	2	1	4	2	3	2	5	2
Social sciences [c]	15	19	15	15	19	23	19	22	28	22	31	31	43	33
Engineering	1	3	4	1	1	7	7	6	11	2	6	10	14	12
	Temporary residents													
Total, all degrees	3,448	3,587	3,940	4,498	5,227	5,612	6,648	9,311	9,953	9,932	9,406	8,810	9,610	8,463
Science and engineering	2,675	2,689	2,983	3,412	4,047	4,468	5,391	7,641	8,092	8,113	7,521	6,994	7,802	6,948
Natural sciences [b]	1,079	1,046	1,140	1,273	1,517	1,704	1,975	2,936	3,213	3,191	2,815	2,501	3,026	2,786
Mathematics/computer sciences	170	181	226	281	327	445	524	846	876	865	791	747	817	730
Social sciences [c]	651	645	675	688	784	787	952	1,226	1,260	1,273	1,262	1,222	1,243	1,036
Engineering	775	817	942	1,170	1,419	1,532	1,940	2,633	2,743	2,784	2,653	2,524	2,716	2,396
	Citizenship unknown													
Total, all degrees	781	868	1,075	1,149	1,376	2,196	2,652	793	947	1,161	734	874	1,299	3,641
Science and engineering	452	472	620	705	823	1,371	1,749	468	641	757	497	545	800	1,894
Natural sciences [b]	170	167	215	215	285	501	582	165	185	247	161	170	299	661
Mathematics/computer sciences	25	20	21	42	40	74	123	24	55	62	30	53	67	149
Social sciences [c]	183	225	269	319	345	529	670	172	226	231	190	180	228	709
Engineering	74	60	115	129	153	267	374	107	175	217	116	142	206	375

[a] Data include all doctorates awarded to U.S. citizens and permanent residents, temporary residents, and people of unknown citizenship.

[b] Natural sciences include physical, earth, atmospheric, oceanographic, biological, and agricultural sciences. Social sciences include psychology, sociology, and other social sciences.

[c] Social sciences include psychology, sociology, and other social sciences.

SOURCE: National Science Foundation, Division of Science Resources Studies, *Science and Engineering Doctorate Awards: 1997,* NSF 99-323 (Arlington, VA: 1999), and previous editions.

Appendix table 7. Full-time S&E graduate students, by source and mechanism of primary support: 1980-95

Year	All mechanisms	Fellowships	Traineeships	Research assistantships	Teaching assistantships	Other	Self-support
	Total number of students						
1980	238,492	20,532	17,550	51,567	53,890	19,446	75,507
1981	242,118	20,106	16,777	52,722	55,746	20,210	76,557
1982	244,830	20,873	14,640	52,580	58,334	20,455	77,948
1983	252,092	21,365	13,514	54,904	60,072	20,960	81,277
1984	253,959	21,638	13,465	57,735	61,257	20,697	79,167
1985	257,351	22,576	13,665	60,995	61,822	20,635	77,658
1986	266,197	22,966	13,526	66,011	62,563	22,246	78,885
1987	271,080	21,965	14,096	70,214	62,859	22,166	79,780
1988	275,204	22,361	14,397	74,588	63,071	21,584	79,203
1989	282,741	23,476	14,527	79,059	64,316	21,082	80,281
1990	292,854	25,269	15,212	80,747	64,973	22,265	84,388
1991	307,049	26,697	15,417	85,175	65,229	22,956	91,575
1992	322,753	28,666	15,376	88,032	65,739	23,565	101,375
1993	329,876	29,170	15,452	90,158	67,344	21,378	106,374
1994	332,453	28,976	15,716	92,033	66,900	21,672	107,156
1995	330,235	28,954	16,108	89,983	66,147	22,294	106,749
	Number with primary support from Federal sources						
1980	52,969	4,635	13,306	29,316	662	5,050	-
1981	50,903	4,093	12,176	29,147	619	4,868	-
1982	47,411	4,097	10,077	28,313	428	4,496	-
1983	47,764	4,118	9,114	29,152	498	4,882	-
1984	47,793	4,125	8,970	29,463	400	4,835	-
1985	49,058	4,423	8,954	30,433	549	4,699	-
1986	51,365	4,600	8,688	32,739	495	4,843	-
1987	53,542	4,449	8,922	34,996	444	4,731	-
1988	55,492	4,569	8,664	36,752	504	5,003	-
1989	57,444	5,177	8,682	38,555	490	4,540	-
1990	59,274	6,316	9,242	38,504	609	4,603	-
1991	63,017	7,447	9,630	40,790	476	4,674	-
1992	65,634	7,761	10,055	42,588	643	4,587	-
1993	67,697	7,515	10,188	44,504	846	4,644	-
1994	68,583	6,945	10,418	45,633	780	4,807	-
1995	67,469	6,904	10,314	44,503	732	5,016	-
	Number with primary support from non-federal sources						
1980	110,016	15,897	4,244	22,251	53,228	14,396	-
1981	114,658	16,013	4,601	23,575	55,127	15,342	-
1982	119,471	16,776	4,563	24,267	57,906	15,959	-
1983	123,051	17,247	4,400	25,752	59,574	16,078	-
1984	126,999	17,513	4,495	28,272	60,857	15,862	-
1985	130,635	18,153	4,711	30,562	61,273	15,936	-
1986	135,947	18,366	4,838	33,272	62,068	17,403	-
1987	137,758	17,516	5,174	35,218	62,415	17,435	-
1988	140,509	17,792	5,733	37,836	62,567	16,581	-

See explanatory information and SOURCE at end of table.

Appendix table 7. Full-time S&E graduate students, by source and mechanism of primary support: 1980-95 (Continued)

Year	All mechanisms	Fellowships	Traineeships	Research assistantships	Teaching assistantships	Other	Self-support
	Number with primary support from non-federal sources						
1989	145,016	18,299	5,845	40,504	63,826	16,542	-
1990	149,192	18,953	5,970	42,243	64,364	17,662	-
1991	152,457	19,250	5,787	44,385	64,753	18,282	-
1992	155,744	20,905	5,321	45,444	65,096	18,978	-
1993	155,805	21,655	5,264	45,654	66,498	16,734	-
1994	156,714	22,031	5,298	46,400	66,120	16,865	-
1995	156,017	22,050	5,794	45,480	65,415	17,278	-
	Percentage of students						
1980	100.0	8.6	7.4	21.6	22.6	8.2	31.7
1981	100.0	8.3	6.9	21.8	23.0	8.3	31.6
1982	100.0	8.5	6.0	21.5	23.8	8.4	31.8
1983	100.0	8.5	5.4	21.8	23.8	8.3	32.2
1984	100.0	8.5	5.3	22.7	24.1	8.1	31.2
1985	100.0	8.8	5.3	23.7	24.0	8.0	30.2
1986	100.0	8.6	5.1	24.8	23.5	8.4	29.6
1987	100.0	8.1	5.2	25.9	23.2	8.2	29.4
1988	100.0	8.1	5.2	27.1	22.9	7.8	28.8
1989	100.0	8.3	5.1	28.0	22.7	7.5	28.4
1990	100.0	8.6	5.2	27.6	22.2	7.6	28.8
1991	100.0	8.7	5.0	27.7	21.2	7.5	29.8
1992	100.0	8.9	4.8	27.3	20.4	7.3	31.4
1993	100.0	8.8	4.7	27.3	20.4	6.5	32.2
1994	100.0	8.7	4.7	27.7	20.1	6.5	32.2
1995	100.0	8.8	4.9	27.2	20.0	6.8	32.3
	Percentage with primary support from Federal sources						
1980	100.0	8.8	25.1	55.3	1.2	9.5	-
1981	100.0	8.0	23.9	57.3	1.2	9.6	-
1982	100.0	8.6	21.3	59.7	0.9	9.5	-
1983	100.0	8.6	19.1	61.0	1.0	10.2	-
1984	100.0	8.6	18.8	61.6	0.8	10.1	-
1985	100.0	9.0	18.3	62.0	1.1	9.6	-
1986	100.0	9.0	16.9	63.7	1.0	9.4	-
1987	100.0	8.3	16.7	65.4	0.8	8.8	-
1988	100.0	8.2	15.6	66.2	0.9	9.0	-
1989	100.0	9.0	15.1	67.1	0.9	7.9	-
1990	100.0	10.7	15.6	65.0	1.0	7.8	-
1991	100.0	11.8	15.3	64.7	0.8	7.4	-
1992	100.0	11.8	15.3	64.9	1.0	7.0	-
1993	100.0	11.1	15.0	65.7	1.2	6.9	-
1994	100.0	10.1	15.2	66.5	1.1	7.0	-
1995	100.0	10.2	15.3	66.0	1.1	7.4	-

See explanatory information and SOURCE at end of table.

Appendix table 7. Full-time S&E graduate students, by source and mechanism of primary support: 1980-95 (Continued)

Year	All mechanisms	Fellowships	Traineeships	Research assistantships	Teaching assistantships	Other	Self-support
	Percentage with primary support from non-federal sources						
1980....................	100.0	14.4	3.9	20.2	48.4	13.1	-
1981....................	100.0	14.0	4.0	20.6	48.1	13.4	-
1982....................	100.0	14.0	3.8	20.3	48.5	13.4	-
1983....................	100.0	14.0	3.6	20.9	48.4	13.1	-
1984....................	100.0	13.8	3.5	22.3	47.9	12.5	-
1985....................	100.0	13.9	3.6	23.4	46.9	12.2	-
1986....................	100.0	13.5	3.6	24.5	45.7	12.8	-
1987....................	100.0	12.7	3.8	25.6	45.3	12.7	-
1988....................	100.0	12.7	4.1	26.9	44.5	11.8	-
1989....................	100.0	12.6	4.0	27.9	44.0	11.4	-
1990....................	100.0	12.7	4.0	28.3	43.1	11.8	-
1991....................	100.0	12.6	3.8	29.1	42.5	12.0	-
1992....................	100.0	13.4	3.4	29.2	41.8	12.2	-
1993....................	100.0	13.9	3.4	29.3	42.7	10.7	-
1994....................	100.0	14.1	3.4	29.6	42.2	10.8	-
1995....................	100.0	14.1	3.7	29.2	41.9	11.1	-

KEY: (-) = not applicable

NOTE: Science and engineering includes the health fields (medical sciences and other life sciences).

SOURCE: National Science Board, *Science & Engineering Indicators--1998,* NSB 98-1 (Arlington, VA: National Science Foundation), appendix table 5-34.

Appendix table 8. Full-time S&E graduate students, by field and mechanism of primary support: 1995

Field	All mechanisms	Research assistantships	Fellowships	Traineeships	Teaching assistantships	Other	Self-support
	Total number of students						
Total S&E	330,235	89,983	28,954	16,108	66,147	22,294	106,749
Total sciences	262,373	62,958	22,921	15,099	55,931	17,289	88,175
Physical sciences	28,892	11,808	2,354	688	11,710	730	1,602
Astronomy	871	439	148	28	225	5	26
Chemistry	16,750	6,466	1,270	445	7,386	372	811
Physics	11,054	4,842	929	215	4,073	349	646
Other	217	61	7	0	26	4	119
Mathematical sciences	13,422	1,451	1,274	222	7,316	675	2,484
Computer sciences	16,564	3,921	924	216	3,364	1,551	6,588
Environmental sciences	11,290	4,661	891	136	2,507	730	2,365
Atmospheric sciences	959	619	67	8	107	69	89
Earth sciences	5,810	2,151	512	59	1,855	334	899
Oceanography	2,228	1,257	195	24	215	166	371
Other	2,293	634	117	45	330	161	1,006
Life sciences	100,132	29,158	8,104	10,942	13,089	6,587	32,252
Agricultural sciences	9,630	5,401	454	146	941	477	2,211
Biological sciences	48,283	19,182	5,395	5,308	9,293	2,143	6,962
Medical sciences	13,863	2,928	1,272	1,661	1,246	1,292	5,464
Other	28,356	1,647	983	3,827	1,609	2,675	17,615
Psychology	35,762	4,626	1,824	1,115	6,152	3,094	18,951
Social sciences	56,311	7,333	7,550	1,780	11,793	3,922	23,933
Anthropology	5,792	452	1,168	132	1,278	344	2,418
Economics	11,746	2,094	1,546	271	3,028	809	3,998
History of science	340	17	127	10	99	18	69
Linguistics	2,486	177	369	50	701	282	907
Political science	17,660	1,624	2,468	777	2,666	1,136	8,989
Sociology	7,353	1,131	915	241	2,145	431	2,490
Other	10,934	1,838	957	299	1,876	902	5,062
Total engineering	67,862	27,025	6,033	1,009	10,216	5,005	18,574
Aeronautical/astronautical engineering	2,693	1,175	262	31	315	377	533
Chemical engineering	5,962	3,100	791	105	907	218	841
Civil engineering	12,248	4,225	924	196	1,850	816	4,237
Electrical engineering	18,303	6,684	1,455	156	3,137	1,439	5,432
Industrial engineering	5,328	1,339	300	37	824	504	2,324
Mechanical engineering	11,119	4,419	942	187	1,950	777	2,844
Materials engineering	3,880	2,535	371	48	352	123	451
Other engineering	8,329	3,548	988	249	881	751	1,912

See SOURCE at end of table.

Appendix table 9. Federal Government as primary source of support, by selected mechanisms and field: 1995

Field	Research assistantships	Fellowships	Traineeships
	Percentage with primary Federal support		
Total S&E	49.5	23.8	64.0
Total sciences	50.6	22.6	65.4
Physical sciences	75.0	33.8	58.0
Astronomy	76.3	50.0	28.6
Chemistry	73.0	31.4	56.0
Physics	77.7	34.7	66.0
Other	52.5	0.0	NA
Mathematical sciences	45.4	23.2	32.4
Computer sciences	61.9	25.6	24.1
Environmental sciences	63.0	33.3	49.3
Atmospheric sciences	81.9	62.7	12.5
Earth sciences	62.3	29.5	47.5
Oceanography	67.5	29.2	58.3
Other	38.0	40.2	53.3
Life sciences	48.1	27.0	77.8
Agricultural sciences	34.5	15.6	10.3
Biological sciences	54.8	29.0	72.6
Medical sciences	39.8	23.6	78.9
Other	30.1	25.6	87.1
Psychology	32.0	17.2	36.6
Social sciences	20.1	13.9	20.6
Anthropology	22.6	18.1	16.7
Economics	25.5	13.3	9.2
History of science	5.9	16.5	40.0
Linguistics	32.8	20.6	34.0
Political science	7.1	10.9	12.5
Sociology	21.0	11.6	51.5
Other	23.4	17.2	25.8
Total engineering	46.8	28.6	43.2
Aeronautical/astronautical engineering	56.9	56.1	58.1
Chemical engineering	45.2	26.3	63.8
Civil engineering	37.4	23.3	16.3
Electrical engineering	49.6	27.8	27.6
Industrial engineering	30.5	20.3	48.6
Mechanical engineering	49.8	33.7	39.6
Materials engineering	54.2	33.4	50.0
Other engineering	47.5	25.0	64.3

KEY: NA = not available

SOURCE: National Science Foundation, Division of Science Resources Studies, Survey of Graduate Students and Postdoctorates in Science and Engineering unpublished tabulations.

Appendix table 10. Number of employed scientists and engineers by sector of employment, broad occupation and highest degree: 1995

Field of Employment	Total	Computer and mathematics scientists	Life scientists	Physical scientists	Social scientists	Engineers
			Total			
All Sectors	3,185,600	949,500	305,300	274,300	317,500	1,339,000
4-year universities and colleges	291,100	41,000	84,300	51,100	71,900	42,800
Other educational institutions	275,200	83,000	64,700	28,500	67,600	31,400
Business/industry for profit	1,970,300	683,200	75,600	138,600	57,600	1,015,300
Self-employed	113,800	23,600	7,400	6,500	42,600	33,800
Non-profit	91,000	27,600	11,000	5,600	33,700	13,200
Federal government	252,400	53,300	37,700	27,600	17,100	116,600
State/local government	191,700	37,900	24,600	16,400	27,000	85,900
			Bachelor's			
All Sectors	1,844,000	625,000	121,500	128,100	60,600	908,800
4-year universities and colleges	63,400	10,500	20,500	11,800	10,800	9,800
Other educational institutions	85,900	34,700	20,000	8,700	8,400	14,200
Business/industry for profit	1,324,800	482,800	39,200	78,800	16,100	708,000
Self-employed	48,800	16,000	3,600	3,100	2,800	23,400
Non-profit	41,100	19,500	4,300	2,200	8,700	6,300
Federal government	150,400	35,100	17,100	12,400	5,700	80,100
State/local government	129,500	26,400	16,800	11,200	8,100	66,900
			Master's			
All Sectors	892,700	268,000	64,000	67,200	135,800	357,900
4-year universities and colleges	45,800	10,000	6,700	7,000	11,400	10,800
Other educational institutions	128,800	39,900	19,900	12,800	42,000	14,200
Business/industry for profit	524,300	179,400	16,700	32,600	26,100	269,600
Self-employed	39,500	6,200	2,100	2,100	21,000	8,100
Non-profit	31,700	6,500	2,200	1,000	16,900	5,200
Federal government	70,800	15,400	10,600	7,400	5,600	31,800
State/local government	51,800	10,600	5,900	4,400	12,800	18,200
			Doctorate			
All Sectors	418,300	53,800	102,400	78,900	113,300	69,900
4-year universities and colleges	181,300	20,400	56,800	32,400	49,700	22,100
Other educational institutions	45,400	8,300	12,900	7,100	14,100	3,000
Business/industry for profit	114,600	18,700	17,800	27,200	14,900	36,000
Self-employed	23,100	1,500	1,300	1,300	16,900	2,100
Non-profit	16,300	1,600	3,900	2,500	6,700	1,700
Federal government	28,400	2,500	8,300	7,700	5,600	4,300
State/local government	9,300	900	1,600	700	5,400	700
			Professional			
All Sectors	30,600	2,700	17,400	200	7,900	2,500
4-year universities and colleges	600	-	400	-	-	100
Other educational institutions	15,100	100	11,900	-	3,100	-
Business/industry for profit	6,600	2,200	2,000	100	600	1,600
Self-employed	2,300	-	300	-	1,900	100
Non-profit	2,000	-	700	-	1,300	-
Federal government	2,800	300	1,700	100	300	400
State/local government	1,200	-	300	-	800	100

KEY: (-) = not applicable

SOURCE: National Science Foundation, Division of Science Resources Studies, Scientists and Engineers Data System (SESTAT) 1995.